

Research Report

DURABILITY OF CULVERT PIPE

by

Jas. H. Havens  
Director of Research

Division of Research  
DEPARTMENT OF HIGHWAYS  
Commonwealth of Kentucky

August 1968

## INTRODUCTION

Almost twenty years ago the Department began to develop durability data on types of culvert materials. In the interim, various stopgap as well as very judicious policies have issued. The present criterion or design practice applicable to Federal Aid projects was affirmed by the Bureau of Public Roads, May 24, 1965. Extensive field surveys have been conducted; various design innovations have been employed; and a "hot" test site has, in a demonstrative way, provided critical life-expectancy records. All past history had been documented previously; however, a brief retrospective summary will provide some continuity between forethought and certain issues now maturing.

1. Performance histories for BCCM culverts at "hot" locations were not available at the beginning--they had to be developed. It was, estimated, perhaps somewhat intuitively, that the coating might persist for at least 15 years.
2. Early surveys disclosed instances of severe corrosive damage to RCP, box culverts, and bridge piers.
3. The test installations at Mortons Gap was conceived responsively to Items 1 and 2.
4. BCCM pipe were accepted for cross-drains and other uses in corrosive areas; field performance histories date therefrom.
5. Terminal data are now forthcoming.

Although the question concerning the adequacy of BCCMP and RCP, in the long-term sense, has been held somewhat in abeyance, pending maturity of terminal statistics, methods of extending the life-expectancy of culverts in "hot" waters have been explored and expediently employed experimentally for yet future evaluation. Thickened-wall RCP were specified on a section of the Western Kentucky Parkway and were recommended for severe locations on the Pennyryle Parkway if encountered. The exact context then was: "Inasmuch as no comparable contrivance or recourse is currently available in behalf of coated-metal pipe, I recommend against its further use in hot environments where long-time durability is desired". An earlier context stated: "The special protection provided in the three instances...reflect a growing concern about the long-time life expectancy of reinforced concrete pipe and coated metal pipe in "hot" locations".

Other contexts pertaining to areal exclusions as well as site exclusions pervade the records. Blanket exclusions have been invoked as expedient and practical controls where risk of potential or latent acidity precluded site-by-site methods of control. With respect to site-by-site control, it was suggested once that "...this type of engineering attention might best be reserved for major projects". Idealistically, however, the only method of control that is not otherwise punitive in its application is a site-by-site method.

The question of adequacy of the two major types of pipe in extreme environments must now be confronted. Failures of BCCM pipe are not mere chance happenings; they are still at the search-and-discover stage--but once discovered,

their existence is undeniable. Chronologically, these discoveries correlate peculiarly with the performance of BCCM pipe at the Mortons Gap Test Site. BCCM pipe at Mortons Gap may be declared terminal. RC pipe at Mortons Gap may also be declared terminal. These conclusions are subject to interpretative concepts and definitions of failure. Photographs are provided herewith.

Summarily, it has been demonstrated that both RC pipe and BCCM pipe do not provide life expectancies of 20 years in environments where the pH is in the range between 3.5 and 2.8. Moreover, 20 years is not commensurate with the expected term of service of a road--which may be 100 years, more or less. This means, of course, that types of culvert pipe which are now specified as standard are not adequate in extreme situations. It means also that the innovations employed earlier were not altogether futile.

It seems reasonable to continue to use current practices in general application but to adopt and implement a practice whereby critical sites or areas may be delineated by surveys and explorations concurrently with the location and design of construction projects. Similar attention should be given to bridge piers and box culverts. Overriding judgment and caution seems admissible in regard to latent or potential acidity that might occur from roadway excavations, mining, and other developments tending to expose offensive materials and ground waters. This would be a site-by-site control.

#### BCCM PIPE

Galvanized, corrugated metal culvert pipe was introduced in 1907.

Paved invert (bituminous, 25 percent of circumference) pipe was introduced in 1925; this was followed by half-coated and paved pipe and then by full-coated and paved pipe. The buildup of paving was referred to as one-dip and two-dip (1928) pipe, etc.

Asbestos-bonded, coated pipe was introduced in 1936.

The first BCCM pipe in Kentucky was installed 5.8 miles east of Jackson, KY 15, near Haddix, in 1928. An existing masonry, box culvert with a concrete slab roof was failing. An 84-inch diameter, full-coated, paved invert, one-dip pipe was threaded into the existing box in the fall of 1928. Figure 1 shows the pipe soon after installation. Saunders Threlkeld (Junior Materials Engineer), reporting on a group inspection, July 14-16, 1941, noted some loss of coating at the outlet. Figure 2 shows the culvert as it was in October 1951. The coating was quite shrunken, and some was missing in the lower half, nearest the ends. The water was found to be altogether inoffensive. KY 15 was reconstructed in 1967.

Another interesting item in Threlkeld's inspection report referred to a 60-inch, regular-dip pipe, which was field-paved with hot-mix asphaltic concrete, installed near Hitchins (Carter County) in 1940 by the C&O Railroad.

Attachment 1 is a copy of a 1945 Special Provision for Bituminous Coated Metal Pipe. There was no provision for coated pipe in the 1945 standards. It is assumed that coated pipe in Kentucky really dates from late 1945 or early 1946. It is noted, therein, that only 3/4 of the circumference was required to be coated and that the minimum thickness was 0.03 inch. Paving of the invert was not specific.

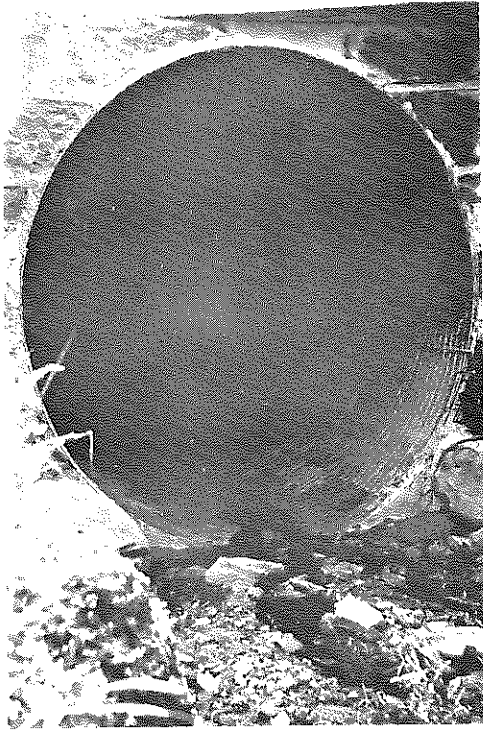


Figure 1



Figure 2

Attachment 2 indicates that coated pipe--arches on state construction date from 1950.

The 1956 Standards required the coating to be not less than 0.05 inch thick and the paving to be not less than 1/8 inch thick (at the crest of corrugations).

BCCM pipe installed at Mortons Gap in April 1951 were identified as:

1. Full-coated and paved, according to Kentucky Special Specification 1-R (two pieces)
2. Full, double-coated only (without paving)(two pieces)
3. Asbestos-bonded, coated and paved (two pieces)
4. Asbestos-bonded, with light bituminous seal (two pieces)
5. Half-coated and paved (two pieces).

Only two pieces of these pipe remain in test, they are:

1. Half-coated and paved
2. Full-coated and paved (Kentucky Special Specification 1-R)\*.

These two pieces are declared terminal; their companion pieces and all other types of metal pipe originally installed (1951) were taken out of test previously.

Figures 3 and 4 show the half-coated and paved piece, April 1968.

Figures 5, 6 and 7 show the full-coated and paved piece, April 1968.

#### RECENT FIELD INSPECTIONS .

Two inspections were made recently on projects brought to our attention by Mr. R. J. Reynolds (Highway Drainage Pipe, Inc.). Prior thereto inspection reports were requested on the Mortons Gap site, the Madisonville By-pass, and the Western Kentucky Parkway---these were submitted June 5, 1958. One of the two, heretofore unreported inspections more or less confirms Mr. Reynolds report dated June 8, 1968. This inspection was made by J. H. Havens and J. W. Scott; Mr. Scott's memorandum report of June 21 is included herewith (Attachment 3). Corrosive water was found in the Straight Creek Area of Morgan County (KY 650 and KY 589); it was attributed largely to sulphur-water springs which seemed to be prevalent---rather than to coal mining.

On July 9, R. J. Reynolds and Bill Reynolds arranged a joint inspection of KY 267 (Rowdy-Harveyton Road in Perry County) and KY 568 (Cranks Creek Road in Harlan County). Both of these roads were constructed under the RS program and were let to contract in September 1949. A brief account of observations follows:

---

\*This is suspected of being a mistake in identity---the pipe may be asbestos-bonded, coated and paved.

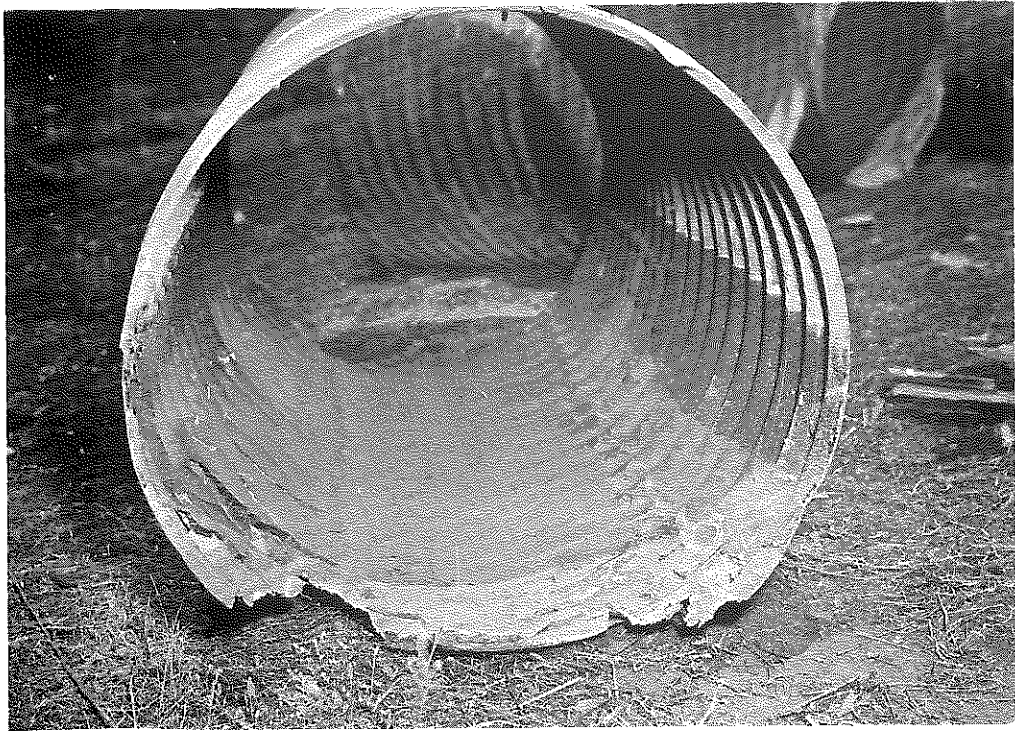


Figure 3



Figure 4



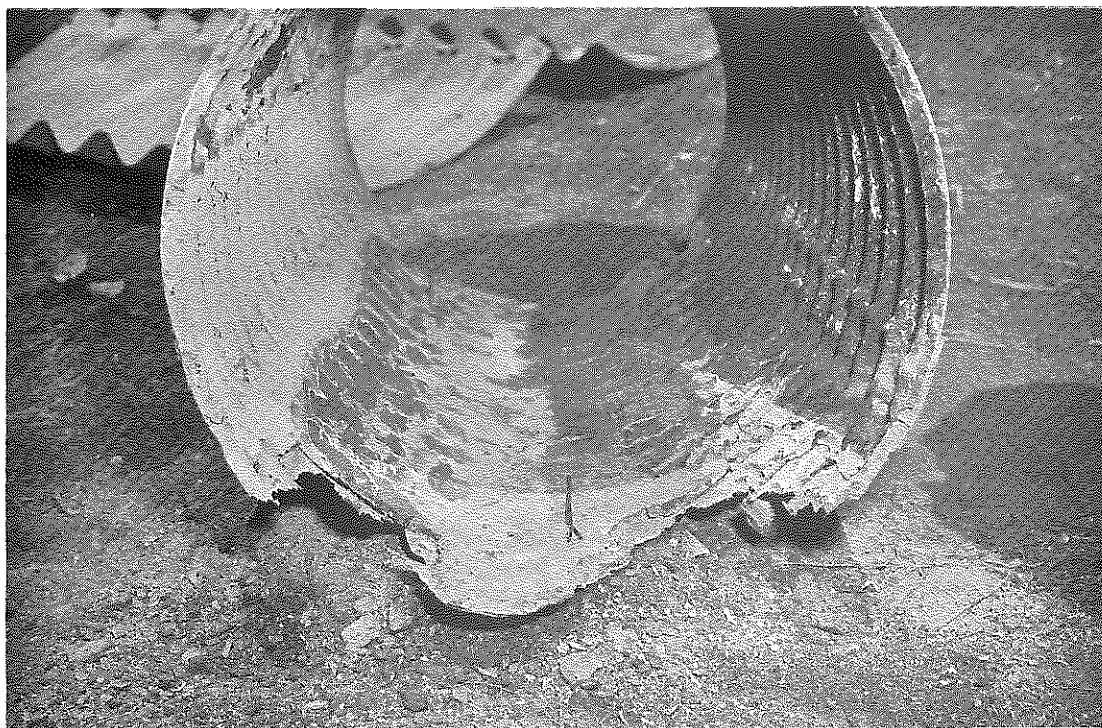


Figure 5

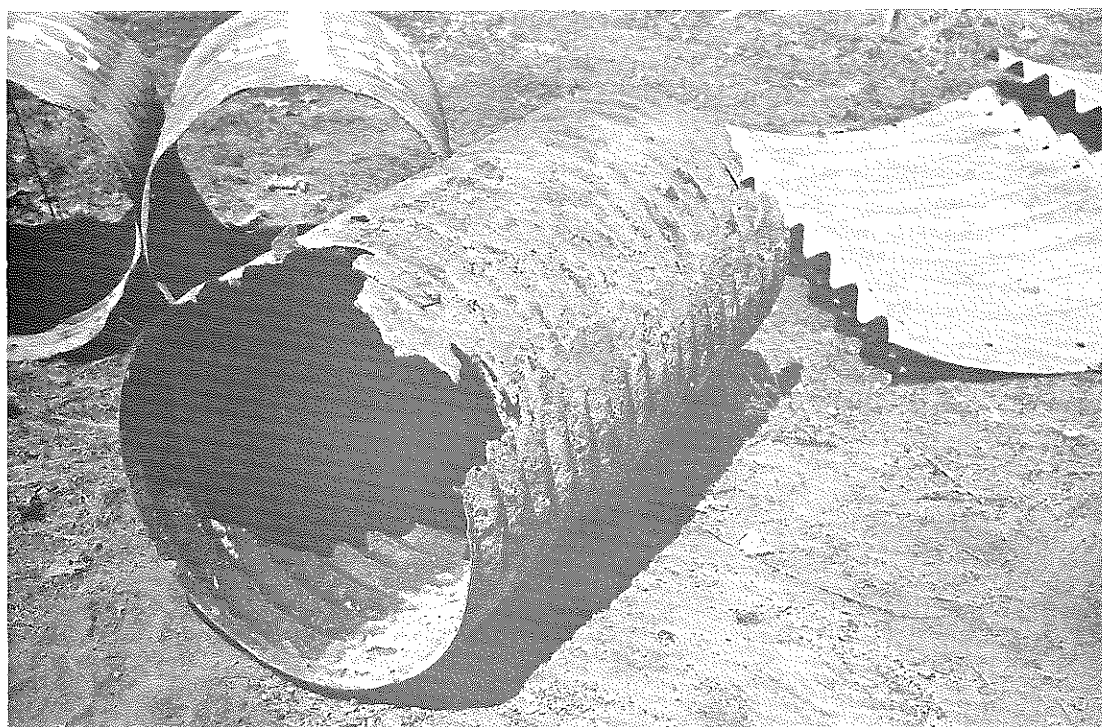


Figure 6



Figure 7



KY 267

1. First structure was a corrugated metal arch on concrete foundation, acid.
2. 1.7 miles; 24-inch drainage BCCM, paved; bottom corroded out 6 feet from end.
3. 4.0 miles, uncoated pipe-arch with concrete or Gunitite paving; reported to have corroded through the bottom before the road was completed; pH 4.5.
4. 4.8 miles; at Lost Creek school; multiplate arch, 93 x 64 inches, uncoated, Gunitite paving (see Figure 8).
5. 5.25 miles; 36-inch BCCM pipe; partly filled, evidence of corrosion; pH 5.0.
6. 5.75 miles, 18-inch, BCCM pipe; coating missing at outlet, metal perforated; abandoned mine site above the road (see Figure 9).
7. 5.60 miles; 48-inch, BCCM pipe; flow line corroded away; drains former mining area; pH 4.0 (see Figure 10).
8. 5.85 miles; 18-inch, BCCM pipe; outlet corroded about an inch inward; pH 4.5.
9. 5.9 miles; 18-inch, BCCM pipe; bottom corroded for several feet inward; pH 4.5.
10. 6.1 miles; 64-inch multiplate arch; uncoated; rust showing on sides; bottom silted; pH 5.5 (see Figure 11).
11. 6.7 miles; large pipe-arch; uncoated, Gunitite paving; former mining areas.

KY 568

1. 0.20 mile; large uncoated pipe-arch; partly filled; rusted at wall; pH 3.5.
2. 0.85 mile; twin BCCM pipe-arches; bottom rusted out at haunches; one partly filled; pH 3.5 (Photographed in 35 mm color, Slides 1 thru 6).
3. 1.1 miles; twin 36 x 22-inch BCCM pipe-arches; badly corroded; one pipe installed upside down; pH 3.5 (Slides 7, 8 and 10).
4. 1.35 miles; twin 77 x 57 -inch pipe-arches; uncoated; Gunitite paving; one partly filled; pH 3.5.
5. 1.65 miles; 42-inch BCCM pipe; dry; coating weathered away at end.
6. 2.05 miles; 77 x 57-inch BCCM pipe-arch; corroded at lip; pH 5.0.
7. 2.55 miles; 66 x 38-inch BCCM pipe-arch; dry; coating weathered on outside and missing inside at the haunches.
8. 2.65 miles; 107 x 72-inch multiplate arch; uncoated; Gunitite paving; pH 5.5 (Slide No. 12).
9. 2.85 miles; 77 x 57-twin pipe-arches; uncoated; one partly filled; Gunitite paving--slightly deteriorated at end; pH 5.0 (Slide No. 14).
10. 3.45 miles; 42-inch BCCM pipe; coating missing at lip; slight corrosion.
11. 3.65 miles; 66 x 38-inches (inaccessible).
12. 3.95 miles; 123 x 77-inch twin, multiplate arches; uncoated; Gunitite paving (Slide No. 14).

Note: Slides filed in Division of Research



Figure 8



Figure 9

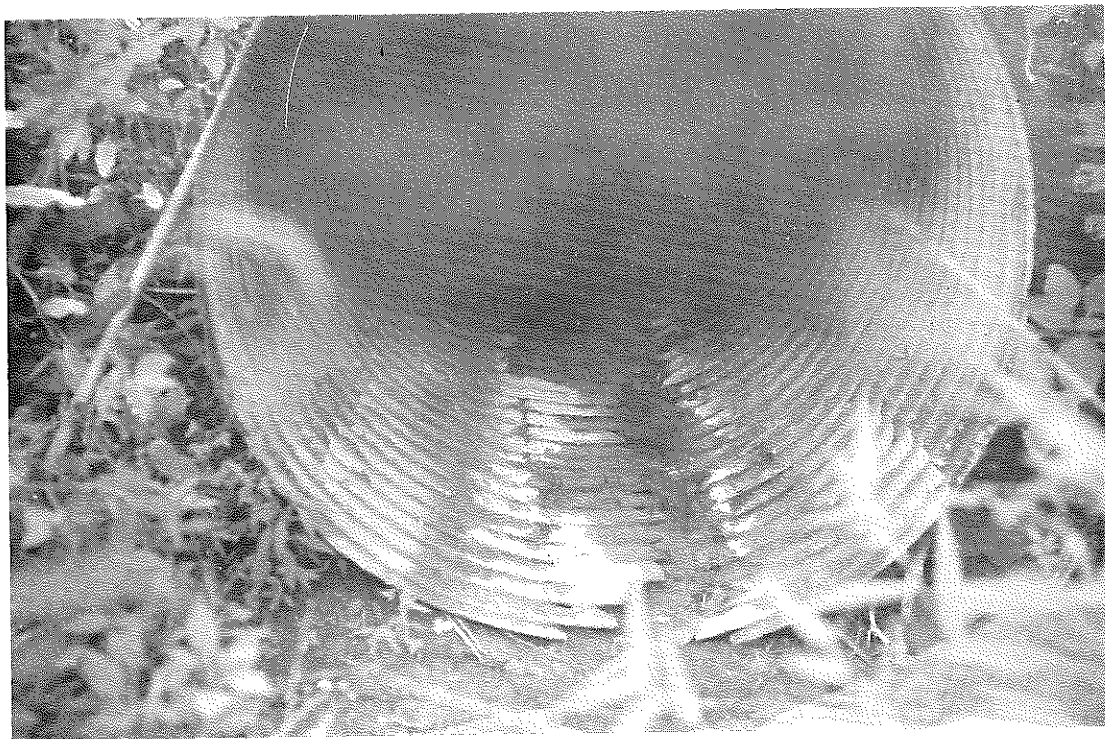


Figure 10

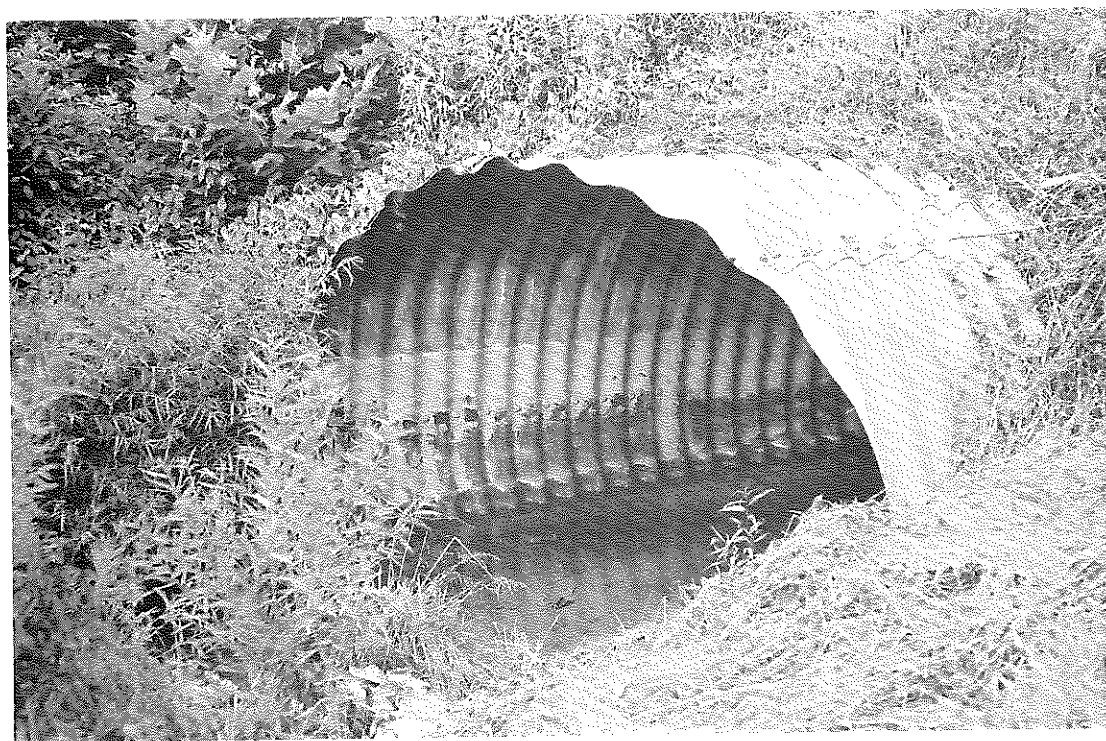


Figure 11

## RC PIPE

No new search-and-discover effort has been directed specifically to reinforced concrete pipe.

It is appropriate perhaps to record here the basis for declaring RC pipe at the Mortons Gap test site as being now terminal. Figures 12 and 13 show the present condition of the RC pipe (gravel aggregate) put into test in April 1951. Figures 14 and 15 show RC pipe manufactured with limestone aggregate and which was put into test September 21, 1954.

The pH there has ranged between 3.5 and 2.8.



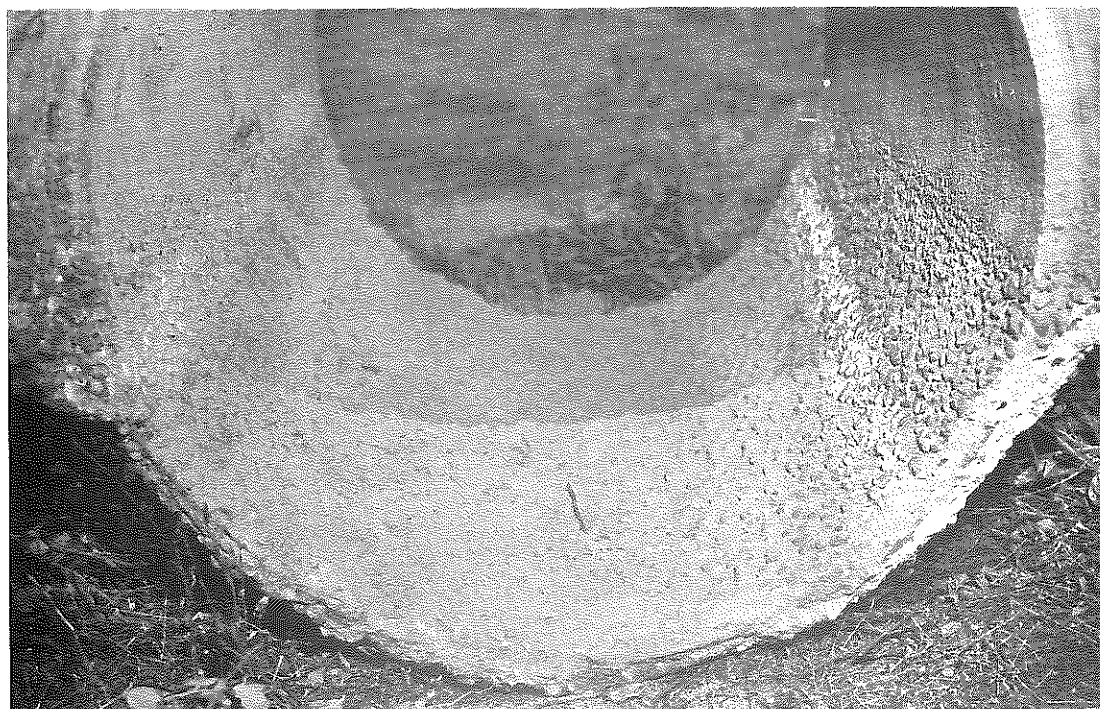


Figure 12

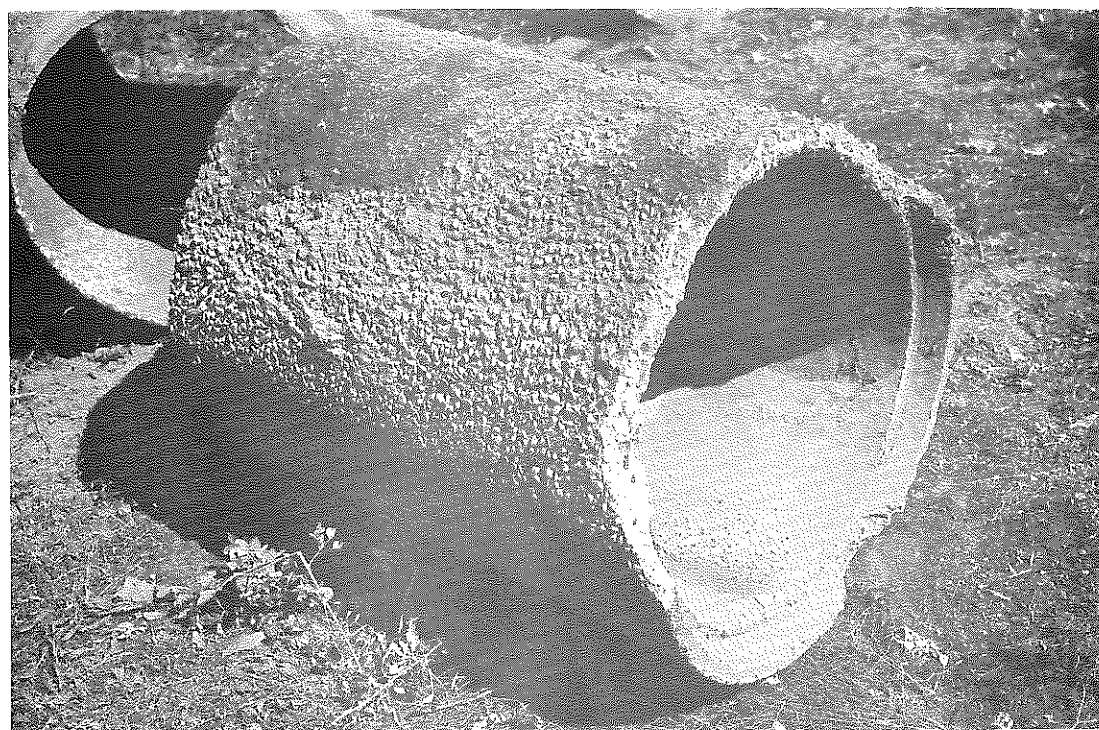


Figure 13



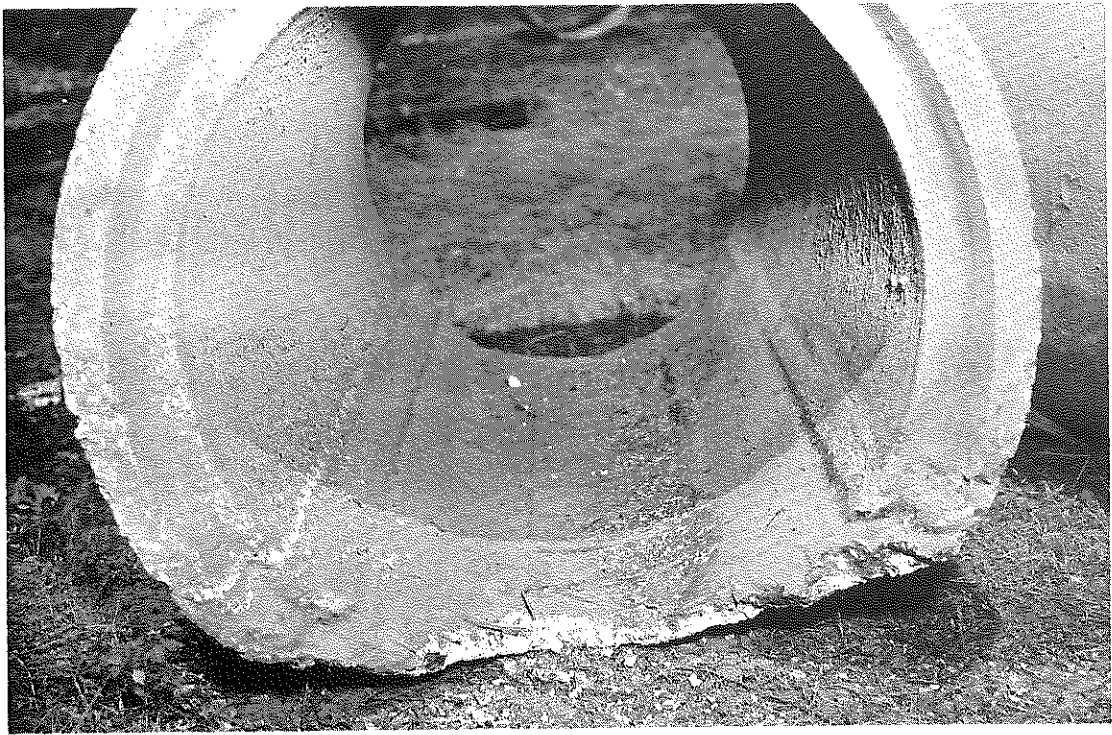


Figure 14

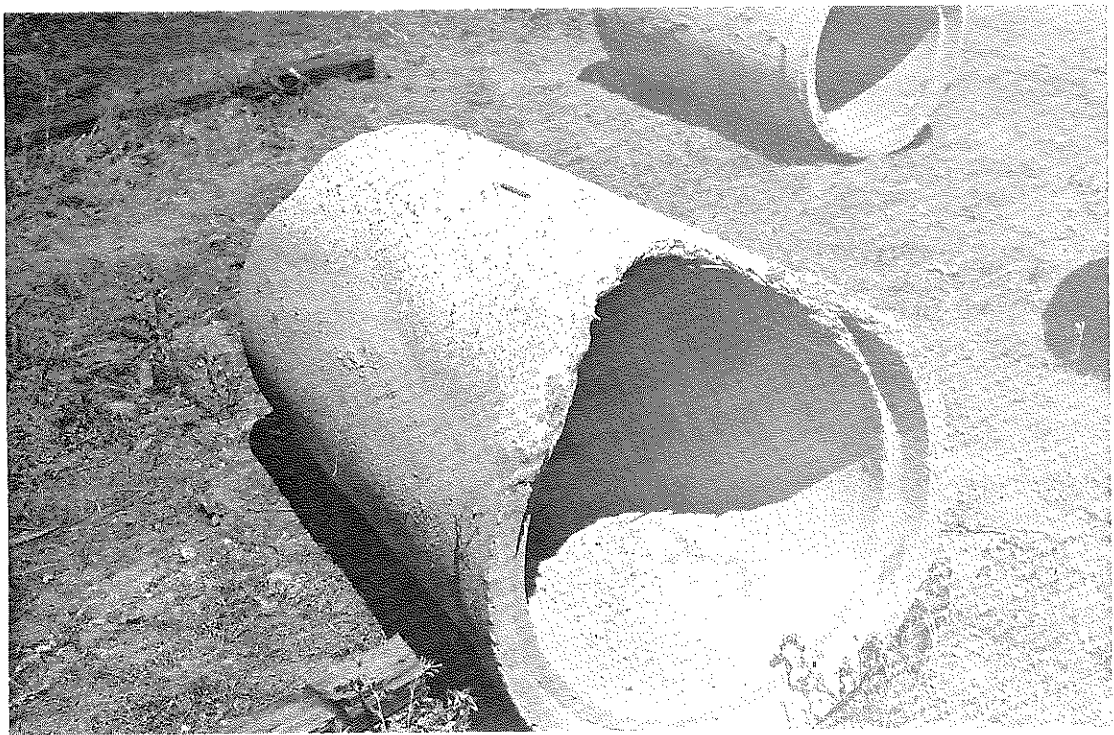


Figure 15

COMMONWEALTH OF KENTUCKY  
DEPARTMENT OF HIGHWAYS

## SPECIAL SPECIFICATION NO. 1-R

## BITUMINOUS COATED CORRUGATED METAL PIPE

This Special Specification No. 1-R covers the material requirements for Bituminous Coated Corrugated Metal Pipe. It shall be applicable when indicated on plans, proposals, or bidding invitations. All specification references are to the Department's 1945 Standard Specifications for State and Federal Road and Bridge Construction.

## BITUMINOUS COATED CORRUGATED METAL PIPE

1. GENERAL. Bituminous coated corrugated metal pipe shall comply with all the provisions of Article 7.8.4 of the Department's 1945 Standard Specifications, including galvanizing, and in addition shall be completely coated inside and out with an asphalt cement, which will meet the performance requirements set forth herein.
  - (a) The asphalt cement shall be 99.5 per cent soluble in carbon bisulphide.
  - (b) Thickness of Coating. The inside of the pipe shall be coated uniformly for three-fourths (3/4) of the circumference (top of pipe when installed) to a minimum thickness of .03 inch. The thickness shall be measured on the crests of the corrugations. The bottom quarter of the circumference shall be of such thickness as to comply with the Erosion Test hereinafter described.
2. PERFORMANCE REQUIREMENTS. The asphalt cement shall adhere to the metal tenaciously; shall not chip off in handling; and shall protect the pipe from deterioration, as evidenced by meeting the following tests successfully:
  - (a) Stability Test. The asphalt cement shall not lose its stability when subjected to the highest summer temperature, as indicated by withstanding the following test successfully.

Parallel lines shall be drawn along the valleys of the corrugations of a representative sample of coated pipe and the specimen placed on end in a constant temperature oven, with the parallel lines in a horizontal position. The temperature of the specimen shall be maintained within 2

degrees F. of 150 degrees F. for a period of four hours. At the end of this time no part of any line shall have dropped more than one-fourth inch.

- (b) Imperviousness Test. The asphalt cement shall be impervious to liquids as indicated by the following test.

A 25 percent solution of sulphuric acid, or a 25 per cent solution of sodium hydroxide, or a saturated salt solution (such as sodium chloride) shall be held in the valley of a corrugation for a period of 48 hours, during which time no loosening or separation of the bituminous material from the galvanizing shall have taken place.

- (c) Erosion Test. A representative sample consisting of a two-foot length of a fully coated pipe (with ends closed by suitable bulkheads) shall be revolved end over end about its transverse axis at a speed of 3.7 revolutions per minute and in such a manner that the erosive charge shall alternately roll along the inner surface of opposite sides of the pipe (inside top and bottom, as when installed in service). At least 75 per cent of the sample shall be immersed, as it revolves, in a bath of water maintained at a temperature of 50°-55° F. The top three-quarters of the pipe, shall not show areas of bare metal more than two inches in length on four of the seven central corrugations after five hours of continuous testing (called a test period), and the bottom one-quarter shall not show a similar failure in nine additional periods of testing. A new erosive charge shall be used for each period of test. The erosive charge shall be 50 pounds of grade MW building brick, conforming to the requirements of the A.S.T.M. Serial Designation C62-44, broken up into pieces two or three inches in diameter, and three gallons of water.

3. PATENTED DEVICES, MATERIALS AND PROCESSES. The Contractor and/or vendor shall hold and save the State harmless from any and all claims for infringement by reason of the use of any patented device, material or process used in the manufacture of the pipe.

APPROVED NOVEMBER 24, 1945

T. H. CUTLER  
STATE HIGHWAY ENGINEER

Specification Mimeograph No. 79  
Stencil Re-cut 4-19-50

COMMONWEALTH OF KENTUCKY  
DEPARTMENT OF HIGHWAYS

## SPECIAL SPECIFICATION NO. 53

## CORRUGATED METAL PIPE-ARCH

This Special Specification No. 53 covers the material requirements for Corrugated Metal Pipe-Arch. It shall be applicable when indicated on plans, proposals, or bidding invitations and, when applicable, shall supersede and void all conflicting requirements of the Department's 1945 Standard Specifications.

## CORRUGATED METAL PIPE-ARCH

1. DESCRIPTION.

Corrugated Metal Pipe-Arch, as designated herein, shall consist of corrugated galvanized metal pipe which has been fabricated to the approximate semi-elliptical shape described hereinafter.

2. GENERAL REQUIREMENTS.

The requirements for base metal, rivets, spelter, inspection, sampling, marking, corrugations, gage, dimensions and weights, end finish, bands, and workmanship shall be as specified in Article 7.8.4 of the Department's 1945 Standard Specifications for circular pipe of equal periphery.

When "Bituminous Coated Corrugated Metal Pipe-Arch" is called for on plans, proposals or bidding invitations, the pipe-arch shall be coated and paved as specified in the current Special Specification No. 1-R for "Bituminous Coated Corrugated Metal Pipe", except that the paved area shall extend up on the sidewalls of the pipe-arch for a vertical distance equal to one-half of Dimension "B" as defined hereinafter.

3. FABRICATION.

Dimensions, tolerances, areas and gages shall be as follows:

DIAMETER OF CIRCULAR PIPE OF EQUAL PERIPHERY	PIPE-ARCH							
	SPAN	RISE	AREA (Sq. Ft.)	GAGE	DIMENSION "B"*	MINIMUM RADIUS OF CURVATURE	PERMISSIBLE VARIATION	
							SPAN	RISE
15"	18"	11"	1.1	16	3 1/2"	2 1/2"	1"	1"
18"	22"	13"	1.6	16	4"	3"	1"	1"
24"	29"	18"	2.8	14	5 1/2"	4"	1"	1"
30"	36"	22"	4.4	14	6 1/2"	4 1/2"	1"	1"
36"	43"	27"	6.4	12	8"	5 1/2"	2"	2"
42"	50"	31"	8.7	12	9"	6 1/2"	2"	2"
48"	58"	36"	11.4	12	10 1/2"	7 1/2"	2"	2"
54"	65"	40"	14.3	12	12"	8 1/2"	2"	2"
60"	72"	44"	17.6	10	13"	9 1/2"	2"	2"

\*Dimension "B" is the vertical distance from the lowest portion of the base to a horizontal line drawn across the widest portion of the arch. A tolerance of plus one inch will be permissible in dimension "B" for the 18" x 11" and the 22" x 13" pipe-arch. A tolerance of plus or minus one inch will be permissible in dimension "B" for the remaining pipe-arches tabulated above.

All dimensions are measured to the inside crests of the corrugations.

Longitudinal laps shall be staggered so as to alternate right and left of centerline a distance of approximately 15 per cent of the periphery.

APPROVED DECEMBER 6, 1949

D. H. BRAY  
STATE HIGHWAY ENGINEER

Specification Mimeograph No. 124



Attachment 3

MEMO TO: Jas. H. Havens, Director  
Division of Research

D.2.2

FROM: J. W. Scott,  
Pr. Research Engineer

DATE: June 21, 1968

SUBJECT: Inspection of Pipe Culverts in Morgan and  
Carter Counties

On June 19, 1968, a number of coated and uncoated metal cross drains were inspected in Morgan and Carter Counties. Generally, it was found that after 19 years of service, coated bituminous pipes in acid streams were still in good condition except for minor rusting; and uncoated metal pipes in nonacid streams were rusted through. Coated and uncoated pipe in service for four years was still satisfactory.

Inspection notes are as follows:

Morgan County; Ky 650; Straight Creek Road; Constructed in 1949.

0.5 mi. N Ky 172 - Bituminous coated pipe, pH 4.5; Six inches of coating partially missing at inlet; good condition.

0.9 mi. N Ky 172 - Uncoated multiplate metal arch- pH 6.0; Slight rusting of flowline.

1.2 mi. N Ky 172 - Uncoated multiplate metal pipe- nonacid, fish observed; At least five feet of flowline rusted through at inlet; Remainder of pipe silted.

Morgan County; Ky 589; Ky 172 - Jeptha Road; Constructed in 1964.

1.0 Mi. S Ky 172 - Bituminous coated pipe- Fifteen feet of coating missing at outlet; Slight rusting of exposed metal.

J. H. Havens

1.7 mi. S Ky 172 - Uncoated multiplate metal arch-  
pH 5.0; Slight rusting of flowline.

1.9 mi. S Ky 172 - Uncoated multiplate metal arch-  
Moderate rusting of flowline.

2.1 mi. S Ky 172 - Bituminous coated pipe - No  
water present; One-half silted.

2.2 mi. S Ky 172 - Bituminous coated pipe-  
No water present; Bituminous coated pipe had  
recently been replaced with a larger diameter  
concrete pipe. The replaced pipe was still at  
the site and was full of silt. Very slight  
rusting of the pipe had occurred.

2.3 mi. S Ky 172 - Bituminous coated pipe-  
Could not examine because of silt.

NOTE: Indications are that new section of roadway  
begins at Jeptha.

Carter County; Ky 773; Hitchens to Ky 7 Road;  
Constructed in 1949.

3.5 mi. E Ky 1 - 24 inch bituminous coated pipe-  
pH 4.5; Two feet of coating was missing at outlet  
and one foot of exposed pipe was rusted through.  
Shoulder cave-in at inlet end not related to pipe.

JWS:j11